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"LUNOKHOD-2" ON THE LUNAR CONTINENT

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Having begun the space era in 1957, the Soviet Union has, /17*
by the launches of automatic space stations of the "Luna," "Zond," "Venera" and "Mars" series, made an important contribution to the development of contemporary comparative planetology — an exceptionally important field of knowledge which has emerged as one of a number of the most promising trends of fundamental scientific investigations.

A View into the Solar System's Past

Noticeable climatic anomalies of recent years have once again emphasized the fact that the living conditions of human society are directly dependent on conditions in the interplanetary medium. Calculations show that even an extremely slight decrease in the average temperature of the Earth's surface resulting from a change in the amount of radiant energy coming from the Sun can, in an extremely short time, lead to glaciation of significant areas with catastrophic disruption of the accustomed way of life of many peoples. On the other hand, the simultaneous release of even an infinitesimal part of the internal energy of the Earth, as volcanic eruptions, earthquakes, seismic sea waves and other such phenomena vividly illustrate, is capable of wiping from the face of the planet cities and whole regions in a few minutes. These examples again and again convince us of the pressing need

*Numbers in the margin indicate the pagination of the original foreign text.

for careful study of the gamut of space factors whose interaction creates the entire range of conditions of the environment in which modern man lives.

The director of the Pulkova Observatory, V. A. Krat, and Dr. Phys.-Mat. Sci., B. M. Rubashev, noted * that "The long-term action of even a comparatively weak factor on the Earth's atmosphere can, in the opinion of many investigators, prove more effective than the action of powerful, but short-term factors." Factors acting over the long term are capable of causing extremely serious anomalies in established natural processes.

The capacity of man to foresee an approaching threat and to mobilize the required energy resources to maintain the necessary ecological balance with the environment is perhaps the basic criterion of his scientific maturity. Therefore, the problem of most fully studying the outer space medium which surrounds man — both with the goal of increasing resistance to its changes on different scales and with the goal of seeking the most efficient use of natural resources — is one of the central problems of modern science. An important place in its solution must belong to investigations of the Moon and the planets by spacecraft.

A study of the Moon, which has not been subject to the errosive action of the amtosphere, the hydrosphere and the biosphere, according to widespread opinion, will serve as the key /18
to understanding the origin and evolution of the solar system. If, under terrestrial conditions, geologists can trace only the last 600 million years of the Earth's development, only in exceptional cases encountering isolated samples of older rock, the very first samples of lunar rock brought scientists information

* Krat, V. A. and B. M. Rubashev. "Caprices of the Sun and the Weather," Pravda, July 1, 1973.

on events in the Solar System which occurred 3 — 4 billion years ago. Certain regions of the lunar continents which are most complex geologically, could in all probability prove to be as old as the "day of creation." According to concepts prevalent today, they could reflect the cosmogonical period when the formation of the Earth occurred.

Besides data on the early evolutionary stages of our planetary system, specifically on the original distribution of chemical elements in the bowels of the planetary bodies, a study of the Moon yields invaluable information as well about those contemporary processes which could cause, for example, the formation of the gigantic rift depressions in the midoceanic ranges and continental drift on the Earth. Hence, further study of the Moon is a fundamental scientific task of the most urgent nature, inasmuch as it opens the way to understanding the general processes of formation and development of bodies of the Solar System nearest to the Earth and simultaneously leads to an understanding of many basic contemporary processes in the Earth's interior and on its surface, on a global scale.

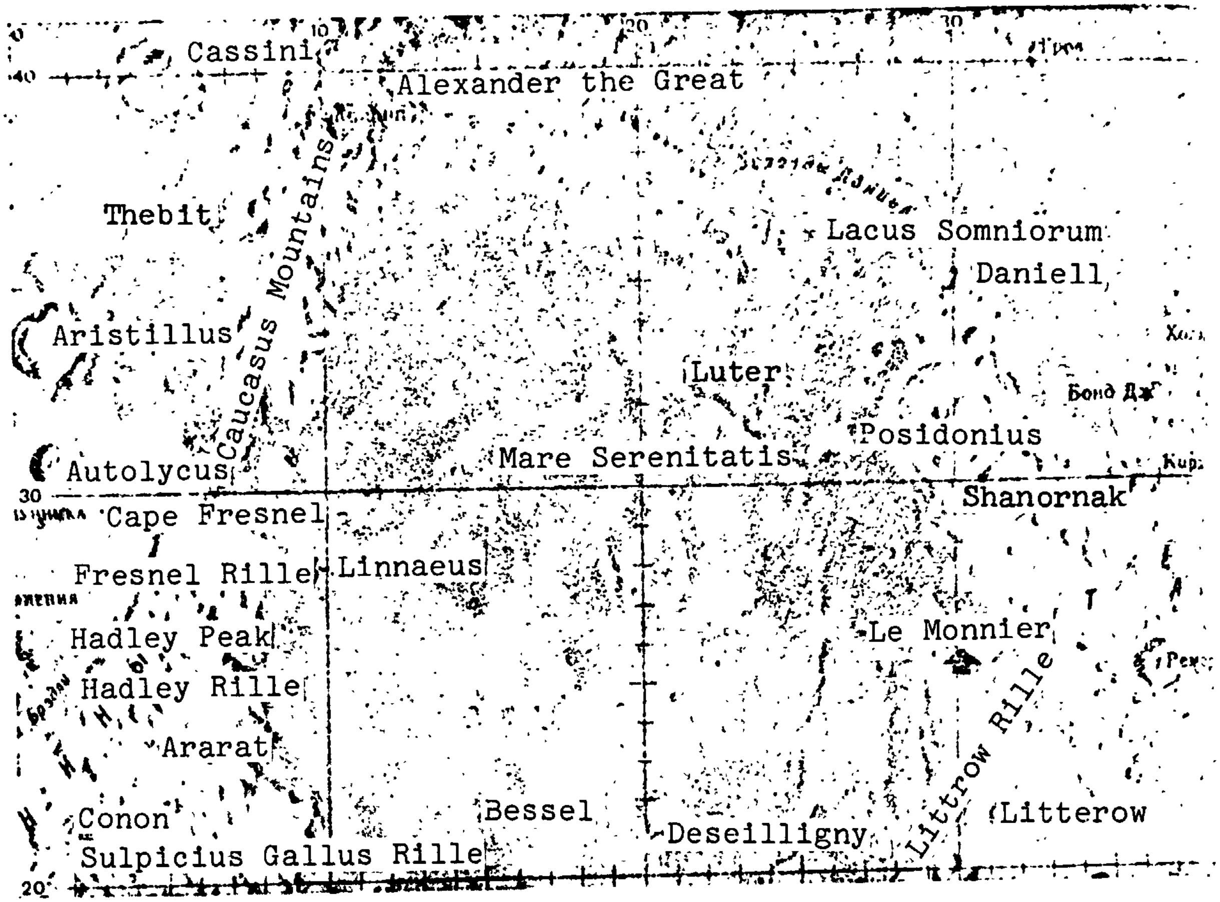
New Facts

Truth is born in disputes. In future disputes, the future of vast scientific trends will also be determined, particularly the future of those which require large capital investments for their development. How could one fail to recall today the foes of the American "Apollo" program, who criticized not only the planning for manned flights to the Moon, but also the very selection of the object of investigation. One of the most important representatives of modern astrophysics and the initiator of many of its trends, F. Hoyle, in his book, "Galactic Nuclei and Quasars," wrote with polemic passion that he personally does not /19 believe that anything at all worthwhile could come from investigations of "that lump of slag that is the Moon." But then at a press conference on the subject of the completion of the "Apollo" program, one of the American selenologists, without hiding the sadness of his colleagues, said: "the Moon has barely begun to tell us something and then...it's over."

Commenting on the premature end of the "Apollo" program, the American reviewer, F. Getlin, wrote: "For those who cannot understand why our Congress turned its back on the Moon, there is a brief and exhaustive explanation: the war in Viet Nam... the "Apollo" program has become a casualty of war."

Actually, the Moon has barely begun to tell us about its long, multistage history, filled with important cosmogonic events. No, it did not prove to be a simple "lump of slag" as Fred Hoyle imagined it to be. The Moon is an ancient and complex natural object which, similar to the Earth, is differentiated into several phase strata. It is an object which carries on its surface the traces not only of prolonged exposure to the interplanetary meteorite stream, but also of active, internal processes as yet not fully known to us.

Based on the rate at which the studies were made and the amount of results achieved, the last decade of lunar investigations is without precedent in the whole history of world science. Following the photographing of the reverse side of the Moon by the "Luna-3" and "Zond-3" automatic Soviet stations, the Soviet station "Luna-9" made the first soft landing on the Moon's surface in February, 1966. Soon the Soviet automatic station "Luna-10" became the first artificial satellite of the Moon. After the first flights came many launches of spacecraft of the "Luna," "Zond," "Surveyor," "Lunar Orbiter," and "Lunar Explorer"



Map of the region of Mare Serenitatis, where the crater Le Monnier is located (north, as on geographic maps, is toward the top, east — to the right; the arrow shows the landing site of "Lunokhod-2").

series. In September, 1968, the Soviet "Zond-5" safely returned to the Earth after circumnavigating the Moon, having become the first spacecraft to cover the Earth-Moon-Earth trajectory. In December, 1968, a similar trajectory was covered by the crew of the manned "Apollo-8" spacecraft. In June, 1969, crew members of "Apollo-11" became the first men to walk on the lunar surface. Up to now, six successful expeditions have been made to the Moon.

In addition to ground samples collected by the crews of the "Apollo" spacecraft, scientists now have a sample of the lunar material brought to the Earth by the Soviet "Luna-16" station* from the eastern region of the Moon, located far in longitude from the center of its visible hemisphere. In February, 1972, the Soviet "Luna-20" first brought a sample of regolith from the lunar continent to the Earth. Somewhat later, material from the Moon was also brought to the Earth by the crews of the "Apollo-16" and "Apollo-17" spacecraft. An important step in the investigation of the Moon was the landing on its surface of the automatic, self-propelled "Lunokhod-1" in Nov., 1970, which continued for ten lunar days. The complex of scientific measurements conducted by the aid of the Moon's artificial satellite — the "Luna-19" automatic station — continued for more than a year.

To sum up the successful accomplishment of the Soviet and American space programs in past years, in the study of the Moon a number of cardinal scientific results were obtained which are of permanent significance. These specifically include the following: the discovery of structural asymmetry of the visible and reverse hemispheres of the Moon; obtaining various data on the lunar soil; the investigation of the composition of rocks in the maria and on the continents; the discovery of mascons; the discovery of magnetization of the rock and much more. It is particularly necessary to note that terrestrial investigations of the Moon by optical methods far from lost their value in these years, making possible regional interpretation of the results of space experiments carried out at separate points of the lunar surface. In combination with the results of intensive investigations of other planets of the Solar System, primarily Venus and

*See A. A. Gurshteyn and K. B. Shingaryeva. Soviet Automatic Spacecraft Investigate the Moon. "Priroda," No. 1, 1971.

Mars, the contemporary scientific results of studying the Moon have created the objective prerequisites for extremely vast development of modern planetology.

The Strategy of Investigations

The problem of investigating and conquering the boundless, ice-hidden expanses of Antarctica serves as a profound analogy of the problem of investigating and conquering the Moon. After the discovery of Anarctica by the distinguished Russian voyagers F. F. Bellinsgauzen and M. P. Lazarev during the round-the-world expedition of 1819 — 1821, the Antarctic continent long remained only the arena of scattered heroic expeditions with the goal of reaching the South Pole of the Earth. Subsequently, the period of activity of the individual traveler-explorers was replaced by the stage of planned and goal-directed investigation of various regions of the Antarctic continent by scientists of different countries. The great significance of Antarctic conditions for the formation of many global processes in the atmosphere and hydrosphere of the Earth became clear, and the need for studying Antarctica for developing scientific concepts concerning the character of evolution of the Earth's surface was clear. The next stage in the study of Antarctica was the formulation of appropriate international-legal agreements on its status, for broad cooperation of the scientists of various countries in the subsequent investigation and conquest of this poorly-accessible region of the globe.

In the study of the Moon, as in the study of Antarctica, it is not enought to limit oneself to data collected at a few scattered points of its surface. In order to better clarify this important fact, we shall attempt to imagine how hypothetical extraterrestrial investigators would compile a clear concept of the Earth only on the basis of a few short visits to the surface of our planet. Could one really determine conditions in the Siberian Taiga, having been only in the African Savannah, or extrapolate the conditions of Antarctica to a village of the Amazon valley? Of course, conditions on the surface of the Moon are much more homogeneous than on the Earth, but this not only does not make things easier, but, to the contrary, significantly complicates the task of the investigator. Reports on certain summarized, averaged characteristics of the lunar surface were obtained as the result of the very first flights to the Moon. But today, the primary problem is that of revealing the specific variations in the properties of the lunar surface and the lunar interior, confined to different geological-morphological regions. /20

One wins not by numbers, but by ability ... this saying also remains true for our day, specifically in the strategy of space investigations, including investigations of the Moon. Correct formulation of pressing problems and efficient selection of methods and means of investigation are the mandatory conditions for effectively solving key scientific problems. It is not without interest in this regard to recall that it was, in fact, the modest, with respect to weight, sample of regolith automatically delivered in February, 1972, by the "Luna-20" station, and first taken from the poorly-accessible region of the Moon, that led to the experimental discovery of great differences in the composition of the lunar maria and continents. The material of the continents proved to be broken, composite grained material of a light grey color with a high content of plagioclase fragments of the anorthosite type. The material brought back by "Luna-20" indicated that the composition of the lunar continents is identical to that of the primeval, undifferentiated material which it was immediately after the accretion of the Moon from the protoplanetary cloud. Moreover, the presence on the Moon's

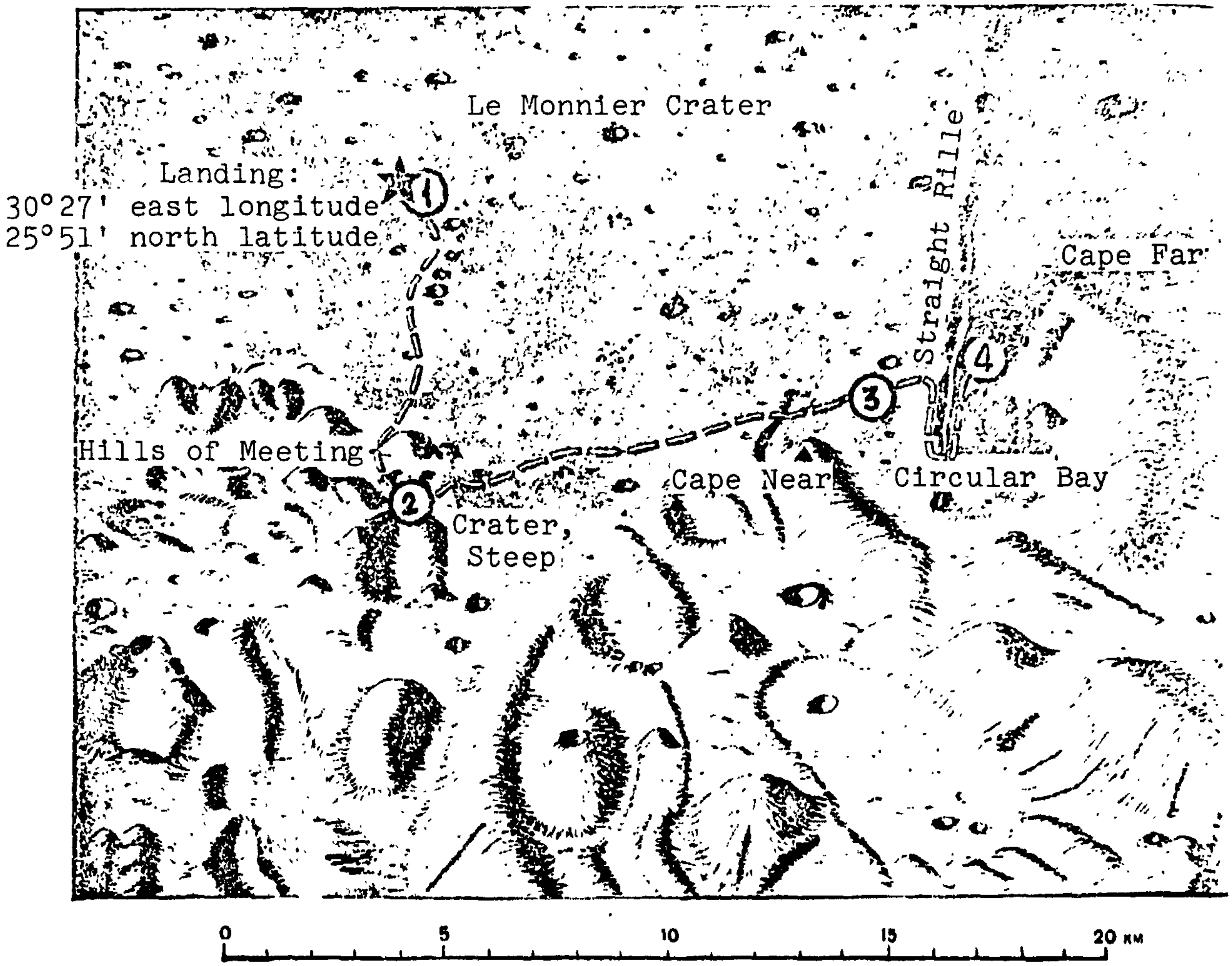


Diagram of movement of "Lunokhod-2" over the Moon's surface. The star marks the landing point of the "Luna-21" automatic station; the figures in circles show stopping places of Lunokhod on the first and successive lunar nights; the drawing of Lunokhod depicts the region where it stopped working (orientation of compass points is the same as on the map). Diagram prepared by G. A. Burva, Institute of Space Research, Academy of Sciences, USSR.

surface of continents of anorthosites which appeared as the result of deep differentiation of the rock, indicates significant differentiation of the primeval Moon even at a very early stage of its existence. These exceptionally important data were not obtained as the result of analyzing the large amount of material /21 brought back to the Earth, but from the characteristics of the region in which samples of the rock were taken.

It is necessary to emphasize the important advantage of automatic methods in comparison with manned flights — their relatively low cost. This makes it entirely justifiable to carry out such highly complex experiments as landing equipment on hard-to-reach regions of the lunar surface which serve as keys in solving many geological and geophysical problems. Flights to such regions are made difficult by the greatly broken relief and consequent severe operational conditions of the on-board apparatus of spacecraft.

Each flight to the lunar mountains will be a severe test of all navigation systems which support the landing of the spacecraft. For manned spaceflights, where emergency situations are directly linked with danger to the life of the cosmonauts, increasing the risk during landing can hardly be considered justifiable. During the flights of automata, however, a slight increase in risk can occur.

At the Boundary of Mare Serenitatis

On the night of 15 — 16 January, 1973, at 01 hours 35 minutes Moscow time, the Soviet automatic station "Luna-21" with "Lunokhod-2" aboard, made a soft landing at the eastern edge of Mare Serenitatis within the 55-kilometer crater Le Monnier.

Mare Serenitatis (second in size after Mare Imbrium among the clearly defined circular lunar maria) belongs to the so-called great belt of circular lunar maria which continues on the reverse side of the Moon in the form of significantly sized circular depressions — thalassoids. The bed of this mare, judging by the complex of accompanying geological-morphological data, belongs among a number of extremely ancient formations of the lunar macrorelief. The inundation of this bed by basalt lavas occurred at a comparatively late stage of the so-called Imbrian period of the lunar history — the period of formation of the lunar maria. Hence, Mare Serenitatis can be considered one of the comparatively young maria on the lunar surface. In the process of formation of Mare Serenitatis, in a fashion similar to that which also occurred during the formation of the other lunar maria, its edge was partially broken up and the bottom of one of the craters which had earlier existed on the continent, 55 kilometers in diameter, was inundated with basalt lavas. This crater on the eastern edge of Mare Serenitatis, which is now located in the zone of contact of the mare and the continent, was named after the French scientist of the 18th century, P. C. Le Monnier. The coordinates of the landing point of the "Luna-21" station are 20°51' northern latitude and 30°27' east longitude. It is located near the poorly defined southern edge of Le Monnier Crater, a total of 5 — 6 km from the sloping, hilly transition zone of the lunar surface, with strongly broken relief, that leads from the surface area to the lunar continent. With respect to the characteristics of the morphological structure and albedo, which are essentially closer to the mare area than the continent, the boundary region outside the limits of Le Monnier to the south of the landing point of "Luna-21" would more correctly be classified as a "precontinent" zone rather than a continent. Distinct from this intermediate zone, from the south-east and toward the crater Le Monnier, runs a continuous region of typical lunar continent toward which, in its turn, runs the Taurus Mountains massif.

At the first stage of its movements to the south from the landing point, "Lunokhod-2" left the confines of the basalt lava in the bottom of Le Monnier Crater, and over the course of a number of sessions, carried out complex investigations in the "precontinent" zone.

Just like its predecessor, "Lunokhod-2" was equipped with two types of television systems. The first of these — the so-called small frame television — serves for transmitting information as the Lunokhod moved along. The second system consists of four pair-mounted, side-carried panoramic phototelevision cameras and serves for transmitting images of unmoving objects at rest. The optical-mechanical principle used in these cameras makes it possible to achieve a high degree of clarity and geometrical accuracy of imagery reproduction. In the field of vision of the phototelevision cameras, optical markers are placed which make it possible to scale photometrically the obtained images. By the aid of both television systems, "Lunokhod-2" transmits a vast volume of information on the studied region's geological-morphological characteristics to the Earth.

The scientific apparatus serving for a complex study of the properties of the lunar surface includes an instrument on both "Lunokhod-1" and "Lunokhod-2" for x-ray spectrometric analysis of the chemical composition of the rock — the RIFMA-M — and an instrument for estimating the physical-mechanical characteristics of the soil in the natural deposit. In preparing the RIFMA-M instrument, a number of changes were made in comparison with "Lunokhod-1," which specifically made it possible to increase the accuracy of determining the iron content. A very important innovation is the installation on "Lunokhod-2" of a tricomponent iron-testing magnetometer which remained on constantly during the movement of lunokhod and at stops. In toto, these instruments make it possible to reveal many characteristics of the structure of the upper crust of the Moon, applicable to the specific geological-morphological situation.

The technical capacities of lunokhod have made it possible to install other apparatus aboard besides the listed instruments, serving to study the surface and depths of the Moon: an astro-photometer for measuring the luminosity of the lunar sky, a radiometer, the "Rubin-1" photoreceiver for experiments using laser direction finding, and also a French corner reflector.

The wealth of practical experience accumulated during the operation of the preceding self-propelled lunar laboratory made it possible to make a number of improvements in the "Lunokhod-2" system; they significantly broadened its maneuvering capacity, speed, and range of movement. This fact made it possible to set much more varied and complex tasks before "Lunokhod-2." /22

After a night stop in the precontinental zone and after carrying out investigations of the environs of a morphological class BC* two-kilometer crater, in the course of its third lunar day of work "Lunokhod-2" made a journey of more than 10 km in an easterly direction. Lunokhod greeted its third lunar night not far from an extensive tectonic fault, which, for the sake of convenience was named the Straight Rille.**

*For more details on the morphological classification of lunar craters, see the collection of articles: Craters and Rocks Tell the History of the Moon, "Priroda," No. 11, 1971.

**Today there are still no universally accepted rules of naming small, so-called topographic objects of the lunar surface. For convenience, in the regions of activity on the lunar surface of various space devices, proper names are given by collectives of specialists participating in the experiments on these spacecraft. The conditional names of objects in the region of activity of "Lunokhod-2" were suggested in the Institute of Space Research of AS, USSR.

Landing stage of the "Luna-21" automatic station on the surface of the Moon. As viewed from one of the television pictures from "Lunokhod-2."

The Straight Rille is a fault with a total length of about 16 km, whose width varies in different places from 200 — 500 m. The depth of the rille reaches 50 m. In several places, the rille is broken by stretches of land which are probably linked with subsequent horizontal displacements of the lunar crust. The orientation of Straight Rille is interesting. It extends perpendicular to the shore line of Le Monnier Crater, thrusting into a clearly defined 5 km bay named the Circular Bay.

Straight Rille is part of an extremely long and branched system of faults characteristic of the entire region of Mare Serenitatis. The fourth lunar day of operation of "Lunokhod-2" was entirely devoted to a detailed investigation of the structure and characteristics of Straight Rille.

The selection of the region of investigation for "Lunokhod-2" was mainly dictated by the pressing nature of the problem of revealing the specific variations of properties of the lunar surface in the zone of the most sharply different geological structures: the mare and the continent. In fact, in such an /23
extremely inhomogeneous region, with respect to its properties,

in comparison with similar data obtained in typical maria and typical continent regions, the general principles could be revealed which will subsequently become the "guiding thread" for understanding the problem of surface evolution of the scale of the entire Moon.

"Lunokhod-2" lived up to the hopes placed on it: already the preliminary processed data contain extremely interesting and highly promising results.

Lunokhod's magnetometer recorded an inhomogeneity of the magnetic field. Subsequent processing of the magnetometric data obtained during the stops of lunokhod will make it possible to reveal the characteristic changes in the lunar field linked with the intensity of the interplanetary field. These changes in the lunar field yield information on the electrical conductivity of its interior at depths on the order of 100 km.

The RIFMA-M instrument detected a systematic change in the chemical composition of the surface layer of the floor of Le Monnier Crater, as the continent was approached and within the limits of the precontinent zone. The first measurements were made a short distance from the landing stage, on the slope of a crater 40 m in diameter. They showed that the iron content is 6 ± 0.6% (as opposed to 10 — 12% in the Mare Imbrium, according to the measurements of "Lunokhod-1"), silicon 24 ± 4%, calcium 8 ± 1%, aluminum 9 ± 1%. During subsequent measurements, the iron content decreased to 4.0 ± 0.4%, while the aluminum content increased to 11.5 ± 1.0%. With the greatest penetration into the precontinent zone, the ratio of silicon content to iron content, in comparison with the first measurements, increased 1.5 times, while the ratio of the aluminum content to iron content increased about 2 times. These data give important information about the character of horizontal mass transport on the lunar surface, and a correlation was found between these data and the reflective properties of the surface in the investigated regions.

A wealth of factual material was obtained on the geological-morphological characteristics of the studied region.

In the mare region where lunokhod moved, forms of relief were /26 encountered such as small craters, and in certain cases — piles of rock in association with them. Most frequently, lunokhod passed near strongly flattened ancient craters. Fresh craters clearly defined in relief were seldom encountered along the route.

During its movement, lunokhod succeeded in evaluating a relative number of the so-called secondary craters which formed as the result of ejecta from the large craters striking the surface. In the range of crater dimensions from 0.5 to 2 m, the number of secondary craters does not exceed 0.25% of the total number of craters this size.

The thickness of the strongly affected surface layer (regolith) fluctuates, judging by the depth of fresh craters whose formation was accompanied by the ejection of fragments of underlying rock from 1 to 6 m. These estimates are in good agreement with those previously available on other mare regions.

The data obtained during the movement of lunokhod along the mare region of the surface served as the standard for measurements under immensely more complex geological-morphological conditions.

In the hilly, precontinent zone, lunokhod reached the outside slope of the bank of a 2 km crater. In this region, landslide terraces extending up to 10 — 15 m were found. Here too, on the

Pile of rocks at the edge of Straight Rille.

slopes of craters having a 15 — 20° gradient, a decrease in the density of small (0.5 — 2 m) craters was noted which was 2 — 3 times less in comparison with the normal "mare" density. The thickness of the regolith within the limits of this hilly plain reaches 10 m in places. In the region of Circular Bay, on slopes with a gradient of 12 — 17°, formations of terrace form were observed which extended significantly further — up to several hundred meters.

As was previously noted, many investigations were carried out in the region of Straight Rille. The time of formation of Straight Rille belongs to the so-called post-mare period of lunar history, i.e., Straight Rille was formed after the floor of Le Monnier Crater was buried by basalt lavas of the mare type. It is not ruled out, however, that the rille is the result of rejuvenation of an ancient tectonic fault whose signs are outlined in the direction of the rille in the continent region far beyond the limits of the crater Le Monnier.

Tectonic faults of the Straight Rille type are objects of the lunar surface extremely interesting in a geological respect which indicate the past occurrence of shifts of vast regions of the lunar crust. Similar to this are the well-studied ancient tectonic seams on the Earth; however, as the result of intensive processes of erosion which occur under terrestrial conditions, as a rule, they are strongly flattened. On the Moon, the tectonic faults are preserved over the course of billions of years and make it possible to observe a vertical cross-section of its surface layer.

On the eastern and western boundaries of Straight Rille, zones of unilateral intensive displacement of the lunar material in the direction of the fault were revealed (width of the zones

— 30 — 40 m). This displacement was caused by the same factors which lead to the formation of the layer of regolith on the whole lunar surface (apparently, mainly micrometeorite bombardment). In the indicated zones, proportional to approaching the rille, due to unilateral displacement of the material the regolith thickness systematically decreases and, on the edge of the fault, rocks of the bedrock base are laid bare in the form of a continuous rock "border," running along the whole length of the investigated part of the rille. Fragments of the discovered rock are frequently 1 — 2 m or more in size. Below the rock "border," the gradient of the rille walls increases and reaches 30 — 35°. Here the slopes are also covered with rubble composed of large rocks and stones.

Hence, in this part of the crater Le Monnier, by the aid of lunokhod, the projection of crust rock several dozen meters thick was established.

We have presented only the preliminary results of the analysis of newly received geological-morphological data; the analysis of these data is being continued by the collective of the Laboratory of Comparative Planetology of the Institute of Space Research, under the supervision of K. P. Florenskiy.

The varied properties of the surface were also established during a study of the physical-mechanical characteristics of the soil, whose supporting capacity fluctuates from 0.1 to 1 — 1.5 kG/cm^2. However, the general distribution of mechanical characteristics of the soil along the surface is quite close to data obtained from "Lunokhod-1."

The results of an experiment in measuring the luminance of the lunar sky, carried out under the supervision of A. B. Severnyy, have attracted great attention. The astrophotometer indicated an unexpectedly high luminance of the daytime and "twilight" (after the setting of the Sun beyond the local horizon) lunar sky, in the visible rays. One of the possible interpretations of this phenomenon is the presence of a layer of dust particles near the Moon, which strongly refract solar light and Earth light in the visible range. However, these data require further experimental verification.

The experiment in laser direction finding of lunokhod proved very successful. The "Rubin-1" photoreceiver installed on board the lunokhod registered a striking laser beam from terrestrial observatories many times. As the result of photographing part of the lunar disk, together with laser notations of direction, it became possible by an independent method to control the location of lunokhod with adequate accuracy.

International Cooperation

For a long time, the surface of Mare Serenitatis was not investigated directly by space methods. Before December, 1972, not a single spacecraft or space device had made a soft landing in Mare Serenitatis. In December, 1972, the last in the American "Apollo" series of spacecraft made a landing in the eastern boundary area of Mare Serenitatis. This was "Apollo-17." The /27
landing point of "Apollo-17" is located practically at the same longitude as the landing point of the Soviet "Lunokhod-2" — a total of 180 km to the south of the landing point of lunokhod. Hence, for the first time in the period of lunar investigations, space devices of the Soviets and the Americans made soft landings close to each other. The data which were collected by the

astronauts of "Apollo-17" and the data which have now been obtained by "Lunokhod-2" can significantly complement each other. In fact, a joint analysis of all the newly obtained information will make it possible to establish new principles for the development of the lunar relief in a zone of contact of one of the lunar maria with the lunar continent which is extremely interesting for understanding the history of the Moon.

Further successes in studying the Moon and the planets of the Solar System will be inseparably linked with an expansion of the front of experimental work, improvement in the technology of space experiments, and with a goal-directed and planned application of the efforts of scientists in this field. As never before in the history of the study of Antarctica, today, in the study of the Moon and planets, the stage of comprehensive and systematic investigations is arriving, in which coordinating the efforts of scientists of different countries and more intimate international cooperation in carrying out complex, long-term scientific programs is of greater importance.

In past decades, astronomers, geophysicists, and geologists of various countries have united many times for collectively accomplishing broad scientific programs serving the goals of the fullest study of characteristics of the structure of the Earth, its natural resources, and the effect of the space environment which determines life on our planet. Among such collective studies, one should point out the International Geophysical Year, conducted in 1957 — 1958, the massive observations in the International Quiescent Solar Year, projects of superdeep drilling of the Earth's crust, and certain others.

Soviet scientists have rich experience in cooperating in the field of space investigations with scientists of the fraternal socialist countries within the framework of the "Interkosmos" program. For several years already, successful cooperation in carrying out space experiments has continued between Soviet and French specialists. The laboratories of many countries of the world have received for investigation samples of the lunar material delivered to the Earth by the "Luna-16" and "Luna-20" stations. Today, as is known, the necessary conditions have come about for realizing certain joint space programs by scientists of the USSR and the USA. Specifically, reports have already appeared in the press on the progress of work in preparing the joint Soviet-American spaceflight in a near-Earth orbit, with docking of two spacecraft. Specialists of the USSR and the USA regularly conduct an exchange of newly obtained samples of lunar soil. Last year, in Wasnington, Soviet-American talks were held on problems of cooperation in the field of lunar chartography. There is obviously no doubt that the planned coordination of efforts of scientists of different countries, in the field of studying outer space, will serve to improve the relationships between peoples and the progress of world science to the benefit of all mankind.

The most important achievements of Soviet science have always been widely adopted in industry and have successfully served as a solution to problems of strengthening the material-technical base of our socialist society. In their turn, the new achievements of Soviet industry have unfailingly led to an expansion of the scientific arsenal and the creation of new research methods. A clear example of such close interaction and mutual enrichment of science and technology is the modern stage of investigations of the Moon by automatic spacecraft.

A large collective of Soviet scientists — mechanics and mathematicians, specialists in the field of studying the Moon, physicists, chemists, opticians, representatives of the most varied fields of knowledge — have been able honorably to solve the combination of scientific problems related to supporting the engineering-design development of new, unified space facilities.

The automatic space devices, delivered to the lunar surface by the aid of universal landing platforms, have today become an irreplaceable tool of further scientific endeavor, a powerful means of expanding our knowledge of nature, which surrounds man.

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16. Abstract

The scientific achievements of the Soviet Union in space research since 1957 are described. The operation of the "Lunokhod" spacecraft on the surface of the Moon is discussed, and the geological-morphological data obtained are itemized.

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